Influence of Sarcopenia on the Development of Physical Disability: The Cardiovascular Health Study

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OBJECTIVES: To examine the temporal relationship between sarcopenia and disability in elderly men and women.

DESIGN: Cardiovascular Health Study, a longitudinal study of cardiovascular disease and its risk factors in older people.

SETTING: Four U.S. communities.

PARTICIPANTS: Five thousand thirty-six men and women aged 65 and older.

MEASUREMENTS: Whole-body skeletal muscle mass was measured at baseline, and subjects were classified as having normal muscle mass, moderate sarcopenia, or severe sarcopenia based on previously established thresholds. Disability was measured via questionnaire at baseline in up to eight annual follow-up examinations. The cross-sectional relationship between sarcopenia and prevalent disability at baseline was examined using logistic regression models. The longitudinal relation between sarcopenia and incident disability over 8 years of follow-up was examined using Cox proportional hazards models.

RESULTS: At baseline, the likelihood of disability was 79% greater in those with severe sarcopenia ($P<.001$) but was not significantly greater in those with moderate sarcopenia ($P=.38$) than in those with normal muscle mass. During the 8-year follow-up, the risk of developing disability was 27% greater in those with severe sarcopenia ($P=.006$) but was not statistically greater in those with moderate sarcopenia ($P=.23$) than in those with normal muscle mass.

CONCLUSION: Severe sarcopenia was a modest independent risk factor for the development of physical disability. The effect of sarcopenia on disability was considerably smaller in the longitudinal analysis than in the cross-sectional analysis. **J Am Geriatr Soc 54:56–62, 2006.**

Key words: skeletal muscle; sarcopenia; disability; longitudinal study

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More than 25% of the elderly population has difficulty or is unable to perform activities of daily living such as climbing a flight of stairs.[1] Many scientists and geriatricians hypothesize that age-related loss in skeletal muscle mass, a condition commonly referred to as sarcopenia, explains in part the high physical disability rate in older people. Sarcopenia is a highly prevalent condition in older people, with 35% of the older U.S. population having a moderate degree of sarcopenia and 10% having a severe degree of sarcopenia.[2] The burden that sarcopenia places on the healthcare system further demonstrates its public health effect. Recent estimates suggest that the healthcare expenditures attributable to sarcopenia in the United States are $18 billion per year.[3]

A number of cross-sectional cohort studies have shown a relationship between sarcopenia, as determined by skeletal muscle mass, and physical disability.[2,4–6] The results from these cross-sectional studies indicate that older adults with severe levels of sarcopenia are approximately two to five times as likely to have disability as older adults with normal muscle mass. A number of studies have also examined the relationship between fat-free mass (skeletal muscle+bone+organ+residual), functional impairment, and disability in older people.[7–9] In general, these studies found weak or nonsignificant effects of fat-free mass, although the percentage of fat-free mass that is skeletal muscle varies between individuals and declines with age.[10,11] Thus, the fact that measures of fat-free mass are a less-sensitive index of sarcopenia than measures of skeletal muscle per se may explain the weak relationship between fat-free mass and disability.

Longitudinal studies have shown that muscle strength, which is in large measure determined by muscle mass, is predictive of functional limitations and disability.[12–14] Thus, it seems logical to assume that sarcopenia precedes disability, but it is also plausible that physical disability itself could lead to sarcopenia. Physical disability would lead to a lower physical activity level, resulting in decreased stimulus to skeletal muscle, which in turn could cause significant muscle wasting over time. Only one longitudinal study has examined the influence of sarcopenia, as determined by muscle mass, on the development of functional limitations or disability. In that study, the risk of developing

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mobility limitations in the lowest quintile of thigh muscle size was 90% greater in men and 68% greater in women.[15] Additional longitudinal studies are needed to confirm these findings. Most notably, the temporal relationship between sarcopenia and more-extreme measures of physical function such as disability needs to be examined.

The primary purpose of this study was to determine whether sarcopenia predicts the onset of disability in older people. A secondary objective was to determine whether sex, age, and health status influence the relationship between sarcopenia and disability.

METHODS

Overview of Study

Subjects consisted of 5,036 elderly men and women from the Cardiovascular Health Study (CHS). Muscle mass categories (normal, moderate sarcopenia, and severe sarcopenia) and disability status (yes or no) were determined at baseline. Disability status was also determined in up to eight yearly follow-up examinations. Using the baseline examination, cross-sectional relationships between muscle mass categories and prevalent disability were determined in all 5,036 subjects. The baseline and follow-up examinations were used to examine the longitudinal relation between sarcopenia and incident disability in the 3,694 subjects without disability at baseline.

Study Sample

The CHS is a population-based study of coronary heart disease and stroke in adults aged 65 and older, as previously described in detail.[16] Briefly, 5,201 men and women were recruited from Forsyth County, North Carolina; Washington County, Maryland; Sacramento County, California; and Pittsburgh, Pennsylvania. Participants were sampled from Medicare eligibility lists in each area. Eligible participants were noninstitutionalized and did not require a proxy respondent at baseline. Of those eligible, 57% enrolled in the study. The baseline examination was conducted between June 1989 and June 1990. The CHS cohort has since been examined annually, and the first eight follow-up examinations were used for analysis. The institutional review boards approved the project at each study site, and written informed consent was obtained from all subjects.

The National Heart, Lung, and Blood Institute (NHLBI) conducted and supported the CHS in collaboration with the CHS investigators. The NHLBI and CHS investigators have created public access data sets that are available to qualified investigators, which were used in the present study. To protect subject confidentiality, some of the variables in the public access data sets were deleted, and some of the continuous variables, such as age, were collapsed into categories or at the extremes.

Baseline and Follow-Up Examinations

The baseline and follow-up examinations consisted of a home (baseline) or telephone (follow-up) interview and a clinical examination, as explained elsewhere.[16] In the interviews, information was obtained on demographics, medical history, socioeconomic status, and disability. The standardized clinical examinations included body composition measurements.

Exposure Variables

Whole-body muscle mass was estimated using bioelectrical impedance analysis (BIA). BIA resistance was obtained using a TVI-10 Body Composition Analyzer (Danninger Medical Technology, Inc., Columbus, OH) with an operating frequency of 50 kHz. BIA measurements were taken between the right wrist and ankle with the subject in a supine position after completion of an overnight fast.[17] Muscle mass in kg was calculated as

$$((\text{height}^2/\text{BIA} - \text{resistance} \times 0.401) + (\text{sex} \times 3.825) + (\text{age} \times -0.071)) + 5.102$$

where height is in cm; BIA-resistance is in ohms; for sex, men = 1 and women = 0; and age is in years.[18] This BIA equation was developed and cross-validated against magnetic resonance imaging measures of whole-body muscle mass in a sample of 269 men and women varying in age (18–86) and adiposity (body mass index (BMI) 16–48 kg/m^2). In that cohort, the correlation between muscle mass predicted using BIA and muscle mass measured using magnetic resonance imaging was 0.93, and the standard error of the estimate for predicting muscle from BIA was 9%. This BIA equation has been used successfully in previous epidemiological studies of sarcopenia and disability.[2,6]

Muscle mass was normalized for height (muscle mass in kg/height in m^2) and termed the skeletal muscle index (SMI). Two approaches were used to group subjects based on SMI. In that first approach, subjects were classified into sex-specific SMI quartiles. In the second approach, participants were classified as having a normal SMI (men $\geq$10.76 kg/m^2, women $\geq$6.76 kg/m^2), moderate sarcopenia (men 8.51–10.75 kg/m^2, women 5.76–6.75 kg/m^2), or severe sarcopenia (men $\leq$8.50 kg/m^2, women $\leq$5.75 kg/m^2) based on established disability-related SMI thresholds.[2]

Covariates

Variables that have been shown to be independently associated with both the exposure and outcome measures were included as confounding variables in the regression analyses and as potential effect modifiers in subgroup analyses.

Age

Age was subdivided into four subgroups (65–70, 71–76, 77–82, $\geq$83). Age was categorized to account for the potential nonlinear effect of age on the relationships examined. These age ranges corresponded to the categories provided in the CHS public access database.

Race

Subjects were classified as white or other.

Socioeconomic Status

Self-reported income was used as a proxy for socioeconomic status. Annual income was categorized as very low ($\leq$$7,999), low ($8,000–15,999), moderate ($16,000–35,999), high ($35,000–49,999), or very high ($\geq$$50,000). Participants with no information on income were coded into a separate category.

Smoking

Lifetime smoking dose was categorized as none, passive (lived with regular smoker), light (1–13 pack-years), moderate (14–50 pack-years), or heavy (>50 pack-years).

Adiposity Status

Weight and height were measured to the nearest 0.5 lb and 0.5 cm, respectively, and BMI was determined as weight (kg) divided by height (m^2). Based on BMI, participants were classified as nonoverweight ($\leq$24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), or obese ($\geq$30.0 kg/m^2).[19]

Cognitive Function

Cognitive function was assessed using the 30-point Mini-Mental State Examination.[20] Cognitive scores were categorized as normal ($\geq$27), mildly impaired (24–26), moderately impaired (18–23), or severely impaired ($\leq$17).

Prevalent Noncardiovascular Diseases

The presence of cancer (present or former) and arthritis at baseline were determined from the medical questionnaire. It was assumed individuals who did not respond to the appropriate questions did not have the disease. Diabetes mellitus status was determined according to the American Diabetes Association classification criteria based on blood glucose levels in a fasting state and in response to an oral glucose challenge.[21] The information needed to calculate incident cases of cancer, arthritis, and diabetes mellitus is not available in the public access CHS database.

Prevalent Cardiovascular Disease

Presence of coronary heart disease, stroke, and congestive heart failure at baseline were determined based on results of the baseline interview and examination. Self-reports of disease were validated by ascertaining medications used, reviewing medical records, and standardized examinations performed on all participants.[16]

Incident Cardiovascular Disease

The method of ascertaining incident coronary heart disease, stroke, and congestive heart disease has been reported previously.[22] Briefly, incident cardiovascular disease cases were ascertained by self-report and from the Health Care Financing Administration hospitalized patient database of *International Classification of Diseases, Ninth Revision,* codes.

Outcome Measures

During the baseline and follow-up examinations, participants were asked a series of instrumental activity of daily living questions that were used to calculate disability scores. The disability score (range 0–6) indicated participants' difficulty performing the following six tasks: heavy housework, light housework, shopping, preparing meals, paying bills, and using the telephone. A score of 0 reflected no difficulty performing any of the tasks, and a score of 6 reflected difficulty performing all tasks.

All participants scoring 1 or higher on the disability score at baseline were considered to have prevalent disability for the cross-sectional analysis. Participants with prevalent disability and participants who did not participate in at least one of the follow-up examinations were not included in the longitudinal analysis. Within the longitudinal sample, incident cases of disability were determined based on disability scores of 1 or higher on any of the follow-up examinations. The first examination in which the participant scored 1 or higher was used to determine the follow-up length for incident disability. For example, for a participant who initially scored 1 (or higher) on the disability score at their 5-year follow-up examination, the follow-up length for incident disability was considered to be the number of days between their baseline and Year 5 examinations. For subjects who died during the follow-up period and did not develop disability before death or who dropped out of the study before developing disability, the length of time between their baseline examination and their last examination was used to determine follow-up length. For subjects who survived until the end of the follow-up period and did not develop disability, the length of time between their baseline and 8-year examinations was used as their follow-up length.

Statistical Analysis

All analyses were conducted using SAS software (SAS Institute, Inc., Cary, NC). For the cross-sectional analysis, logistic regression models were used to determine the odds ratios for prevalent disability associated with muscle mass categories. For the longitudinal analysis, Cox proportional hazards regression models were used to determine the relative risks of incident disability associated with muscle mass categories. The method used to determine follow-up length for the Cox models has been explained in detail in the Outcome Measures section. Age, race, socioeconomic status, adiposity, smoking, cognitive function, and prevalent disease (arthritis, diabetes mellitus, cancer, coronary heart disease, stroke, congestive heart failure) were included as covariates in the logistic and Cox regression models. Incident cases of coronary heart disease, stroke, and congestive heart failure were also included as covariates in the Cox models. Subgroup analyses were performed to determine the potential moderating effect of sex, age, and disease status on the relationships between sarcopenia and disability.

RESULTS

The descriptive characteristics of the 5,036 participants who were part of the cross-sectional analysis are listed in Table 1. When the sex-specific SMI cutpoints were applied, 70.7% of the men and 41.9% of the women had moderate sarcopenia, whereas 17.1% of the men and 10.7% of the women had severe sarcopenia.

Figure 1 (top panel) illustrates the results of the cross-sectional analysis. The likelihood of disability was greater in those with severe sarcopenia than in those with normal muscle mass ($P<.001$), but it was not greater in those with moderate sarcopenia than in those with normal muscle mass ($P=.38$). To examine the potential moderating effect of sex, age, and disease status on the cross-sectional findings, subgroup analyses were performed (Table 2). Similar patterns were seen in all subgroups, but the relationships were stronger in men than women and stronger in those aged 65 to 74 than in those aged 75 and older.

The baseline characteristics of the 3,694 participants who were part of the longitudinal analysis are shown in Table 1. When the sex-specific SMI cutpoints were applied,

Table 1. Characteristics of Participants in the Cross-Sectional and Longitudinal Analyses

Characteristics	Cross-Sectional Analyses (n = 5,036)	Longitudinal Analyses (n = 3,694)
	%	
Male	43.6	46.8
Age		
65–70	42.7	46.2
71–76	32.7	33.0
83–89	18.2	16.1
≥90	6.4	4.7
White	94.7	95.1
Lifetime smoking dose		
None	46.4	45.5
Passive	4.0	3.8
Light	12.2	12.6
Moderate	25.0	26.0
Heavy	12.3	12.1
Socioeconomic status		
Very low	13.1	14.1
Low	9.8	10.5
Moderate	34.0	35.1
High	25.7	25.2
Very high	11.0	8.9
Unknown	6.5	6.3
Body mass index		
Nonoverweight	39.7	40.2
Overweight	42.2	43.1
Obese	18.1	16.8
Ever had cancer	14.9	14.0
Prevalent diabetes mellitus	15.3	13.9
Prevalent arthritis	50.9	44.6
Prevalent coronary heart disease	19.4	15.4
Prevalent stroke	3.9	2.9
Prevalent congestive heart failure	4.4	2.3

71.5% of the men and 44.1% of the women had moderate sarcopenia, while 15.8% of the men and 9.3% of the women had severe sarcopenia. Over the 8-year follow-up period, 49.0% of the men and 57.4% of the women developed disability.

The results of the longitudinal analyses are shown in Figure 1 (bottom panel) and Table 3. The risk of developing disability was greater in those with severe sarcopenia than in those with a normal muscle mass ($P = .006$), but it was not greater in those with moderate sarcopenia than in those with normal muscle mass ($P = .23$). Subgroup analyses revealed significant ($P < .05$) effects of severe sarcopenia on disability risk in women (but not men), in both age groups examined, and in those free of major disease at baseline (but not in those with cardiovascular disease).

The analyses for the entire cohort were repeated using sex-specific quartiles of SMI to categorize subjects. In the cross-sectional analysis, the odds ratios for disability in comparison with Quartile 4 (highest muscle mass) were 0.97 (95% confidence interval (CI) = 0.79–1.20, $P = .80$) in Quartile 3, 1.08 (95% CI = 0.87–1.35, $P = .47$) in Quartile 2, and 1.49 (95% CI = 1.19–1.88, $P < .001$) in Quartile 1. In the longitudinal analysis, the hazard ratios for disability in comparison with Quartile 4 were 0.92 (95% CI = 0.81–1.05, $P = .23$) in Quartile 3, 0.99 (95% CI = 0.86–1.14, $P = .89$) in Quartile 2, and 1.12 (95% CI = 0.97–1.30, $P = .13$) in Quartile 1.

DISCUSSION

The primary finding was that sarcopenia was an independent risk factor for disability, although the effect of sarcopenia was small because the risk of developing disability was only 27% greater in individuals with severe sarcopenia. Furthermore, sarcopenia was not an independent risk factor for disability in men or in individuals with cardiovascular disease.

The longitudinal analysis did not detect as strong a relationship between sarcopenia and disability as was detected in the cross-sectional analysis (Figure 1) or as reported in earlier cross-sectional studies. The risk estimates associated with severe sarcopenia were almost three times larger in the cross-sectional analysis than in the longitudinal analysis (79% vs 27%). In general, previous cross-sectional studies have reported that older adults with severe levels of sarcopenia are about two to five times as likely to have functional impairment or disability as older adults with normal muscle mass.[2,4–6] In short, the results of the present study indicate that the effects of sarcopenia on the development of disability may not be as strong as previously hypothesized based on cross-sectional observations.

Because the influence of sarcopenia on the development of disability appears to be weaker than what was suggested from cross-sectional observations, it implies that the nature of the relationship between sarcopenia and disability is bidirectional. That is, sarcopenia leads to disability, and disability in turn leads to sarcopenia. This pattern of relationship is biologically plausible. Physical disability would lead to a reduced physical activity level, a reduced physical activity level would result in decreased anabolic stimulus to skeletal muscle, and the decreased anabolic stimulus to skeletal muscle would cause significant muscle wasting over time. A number of other factors that were not measured here (e.g., nutrition, inflammation, hormonal changes, protein turnover) may also be implicated in sarcopenia, disability, and the relationship between them.

The findings reported here are consistent with those of a previous study[23] that indicated that sarcopenia in the absence of obesity (76% of the sarcopenic group) was not a significant risk factor for disability in a sample of 451 elderly men and women from the New Mexico Aging Process Study, although in that study, sarcopenia in the presence of obesity (24% of the sarcopenic group), a condition coined sarcopenic-obesity, was associated with a 2.6 times greater risk of developing disability.[23] Thus, sarcopenia may not be a risk factor for disability in the absence of obesity, and most people with sarcopenia are not obese.[23,24] Further studies are required to explore the relationship between sarcopenia and obesity and to examine the effect of sarcopenia per se and sarcopenic-obesity on the development of disability.

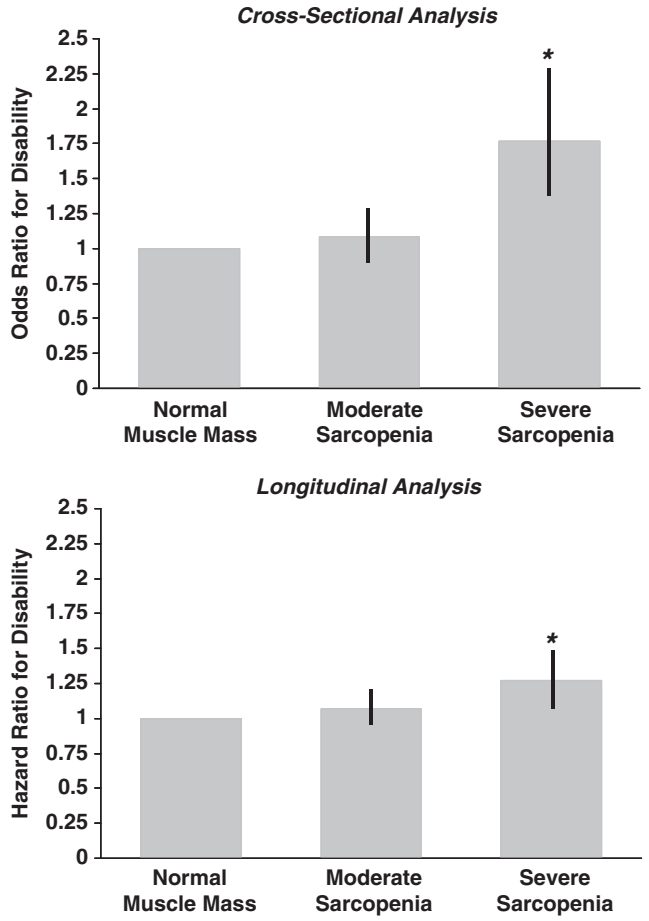

Figure 1. Cross-sectional analysis: Odds ratios for disability according to baseline categories of muscle mass. Longitudinal analysis: Hazard ratios for disability according to baseline categories of muscle mass. For both analyses, subjects with a normal muscle mass were used as the referent category. The height of the bars represents the odds ratio or hazard ratio, whereas the error bars represent the 95% confidence intervals.

The finding of this study that sarcopenia was a modest predictor of disability is somewhat inconsistent with new findings of another study that analyzed data from the Health, Aging and Body Composition Study.[15] In that study, muscle size was measured using computed tomography of the mid-thigh in 3,075 well-functioning black and white women aged 70 to 79. The risk of developing mobility limitations over 2.5 years in the lowest-muscle-size quintile was 90% higher in men and 68% higher in women compared to the highest-muscle-size quintile. These authors found a considerably stronger effect of sarcopenia than was found in the present study, in which the risk for disability was only 27% greater in those with severe sarcopenia. Possible explanations for this difference include measurement of regional (mid-thigh) versus whole-body muscle, measurement of mobility versus disability, inclusion of well-functioning subjects alone versus subjects with different functioning levels, and the use of more-precise measures of muscle in the previous study (computed tomography vs BIA).

A previous report based on the CHS cohort examined the effects of fat-free mass on the development of disability over 3 years. In that study, low fat-free mass was not a risk factor for disability. Conversely, the present 8-year follow-up study found that very low muscle mass was a modest independent risk factor for disability. The disparities between studies may reflect that measures of fat-free mass are a less-sensitive index of sarcopenia than measures of muscle mass per se, the differences in follow-up length, or the differences in the means by which sarcopenia was classified (tertiles vs predefined cutpoints). This study used recently derived sarcopenia cutoffs that were developed based on the relationship between whole-body muscle mass and disability in a representative sample of older Americans.[2] The present study is the first to confirm the applicability of these cutpoints.

A sex difference was found in the longitudinal relation between sarcopenia and disability, with sarcopenia a risk factor in women but not men. The reasons for this sex difference are unclear and are inconsistent with cross-sectional observations. The cross-sectional analyses in this study and two previous studies[2,25] indicates that muscle size is more strongly related to functional performance and disability in older men than in older women. Nonetheless, the observation that sarcopenia had a greater effect on disability in

Table 2. Disability According to Muscle Mass Category (Cross-Sectional Analyses)

Group	Moderate Sarcopenia	Severe Sarcopenia
	Odds Ratio (95% Confidence Interval)	
All subjects (n = 5,036)	1.08 (0.90–1.30)	1.79 (1.39–2.31)‖
Men (n = 2,194)*	1.39 (0.94–2.09)	2.17 (1.35–3.55)‖
Women (n = 2,842)*	1.03 (0.83–1.27)	1.77 (1.28–2.44)‖
Age†		
65–74 (n = 3,317)	1.14 (0.90–1.44)	2.15 (1.49–3.08)‖
≥75 (n = 1,719)	1.00 (0.74–1.34)	1.52 (1.06–2.19)‖
Free of major disease (n = 1,460)‡	1.20 (0.77–1.91)	1.79 (0.99–3.22)
Prevalent cardiovascular disease (n = 1,167)§	0.93 (0.66–1.31)	1.78 (1.10–2.91)‖

Note: Normal muscle mass was used as the referent group.
Odds ratios were adjusted for sex (except*), age (except†), race, adiposity status, smoking status, cognitive function, socioeconomic status, and disease status (diabetes, arthritis, cancer, coronary heart disease, stroke, congestive heart failure) (except‡).
‡ Analysis limited to individuals free of diabetes mellitus, arthritis, cancer, coronary heart disease, stroke, and congestive heart failure.
§ Analysis limited to individuals with coronary heart disease, stroke, or congestive heart failure.
‖ Significantly higher risk ($P < .05$).

Table 3. Hazards Ratios for Disability According to Muscle Mass Category (Longitudinal Analyses)

Group	Moderate Sarcopenia	Severe Sarcopenia
	Odds Ratio (95% Confidence Interval)	
All subjects (n = 3,694)	1.07 (0.96–1.21)	1.27 (1.07–1.50)‖
Men (n = 1,730)*	1.08 (0.86–1.34)	1.20 (0.90–1.61)
Women (n = 1,964)*	1.09 (0.94–1.25)	1.37 (1.10–1.72)‖
Age†		
65–74 (n = 2,587)	1.03 (0.89–1.19)	1.34 (1.06–1.69)‖
≥75 (n = 1,107)	1.19 (0.97–1.46)	1.37 (1.05–1.80)‖
Free of major disease (n = 1,276)†	1.15 (0.89–1.40)	1.50 (1.10–2.05)‖
Prevalent cardiovascular disease (n = 673)§	1.07 (0.82–1.40)	0.96 (0.64–1.46)

Note: Normal muscle mass was used as the referent group.
Odds ratios were adjusted for sex (except*), age (except†), race, adiposity status, smoking status, socioeconomic status, cognitive function, prevalent disease (diabetes mellitus, arthritis, cancer, coronary heart disease, stroke, congestive heart failure) (except†), and incident cardiovascular disease (coronary heart disease, stroke, congestive heart failure).
† Analysis limited to individuals free of diabetes mellitus, arthritis, cancer, coronary heart disease, stroke, and congestive heart failure at baseline.
§ Analysis limited to individuals with coronary heart disease, stroke, or congestive heart failure at baseline.
‖ Significantly higher risk ($P < .05$).

women makes sense from an ecologic perspective. That is, older women have a smaller muscle mass than older men,[2,6,10] which is consistent with the higher rate of disability in older women.[1,26] Another interesting observation in this study was that sarcopenia was not a risk factor for the development of disability in individuals with cardiovascular disease at baseline. This was surprising given that the prevalence of disability is high in individuals with cardiovascular disease and that various forms of cardiovascular disease are associated with accelerated muscle wasting.[27,28] Additional studies are needed to further explore the temporal nature of the relationship between muscle wasting and disability in cardiovascular disease patients.

The strengths of this study include the large sample size and the longitudinal design. One of the biggest limitations was that the exposure variable, muscle mass, was estimated using BIA. There is a strong correlation (correlation coefficient = 0.93) between criterion measures of muscle and estimates of muscle obtained using BIA, and BIA has been shown to provide valid estimates of muscle mass.[18] Furthermore, the BIA equation and method employed here have been used successfully in previous epidemiological studies of sarcopenia and disability.[2,6] Nonetheless, because BIA is not the most-precise method for measuring muscle, the results were likely biased toward the null hypothesis and the true risks of sarcopenia were likely underestimated. Another limitation was that muscle mass was only measured at a single time (baseline). Some of the subjects who were originally nonsarcopenic would have developed sarcopenia during the follow-up and the rate of muscle loss during the follow-up period would have varied. The inability to consider changes in muscle and incident cases of sarcopenia may have diluted the strength of the longitudinal relationships.

In summary, severe sarcopenia was a modest risk factor for the development of disability in older women but not in older men. The influence of sarcopenia on disability was considerably stronger in cross-sectional than in longitudinal analysis. Additional longitudinal studies are required to confirm the findings reported here.

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